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REVIEW

Effects of combined training in individual with Intellectual and Developmental Disabilities: a systematic review and meta-analysis of randomized controlled trials

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ABSTRACT

Purpose of the article: This study aims to evaluate the literature, peer-reviewed clinical trials investigating the effects of combined exercise interventions on individuals with Intellectual and Developmental Disabilities.

Materials and methods: Various databases, using various descriptors and Boolean operators were utilized.

Results: Eight studies meet the eligibility criteria. Regarding the anthropometric measures/body composition variable, the meta-analysis revealed that combined physical exercise did not have a significant effect (standard mean difference (SMD) = -0.16; 95% CI, -0.34 to 0.03; $Z=1.68$; $p=0.09$). For the lipid profile variable, the combined exercise interventions did not show a significant effect (SMD = -0.07; 95% CI, -0.43 to 0.29; $Z=0.38$; $p=0.71$). Combined exercise training had a significant effect on increasing functional capacity (SMD = 0.28; 95% CI, 0.01 to 0.54; $Z=2.03$; $p=0.04$), cardiorespiratory function (SMD = 0.80; 95% CI, 0.34 to 1.26; $Z=3.41$; $p\leq 0.001$), and strength (SMD = 0.77; 95% CI, 0.45 to 1.08; $Z=4.78$; $p\leq 0.001$).

Conclusions: Participants from the intervention group that took part in combined exercise training showed a higher probability of improving their functional, cardiorespiratory, and strength capacity compared to the control group.

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> IMPLICATIONS FOR REHABILITATION

- This study synthesises the literature, peer-reviewed clinical trials investigating the effects of combined exercise interventions on individuals with Intellectual and Developmental Disabilities.
- Participants who performed combined physical exercise were more likely to improve their functional, cardiorespiratory and strength capacity compared to the control group.
- Professionals (e.g., rehabilitation technician, exercise technician) responsible for planning interventions for people with IDD should consider the results of this study when planning their interventions, particularly regarding the prescription of physical exercise, as well as monitoring training and several important variables that can be enhanced by regular physical exercise.
- Organisations that provide support to people with IDD (support or social solidarity institutions) should also consider the results of this study, to provide the necessary conditions (materials, spaces or human resources) so that professionals could plan this type of intervention in the most appropriate and adapted way possible for the individual.

Introduction

Intellectual and developmental disabilities

The International Classification of Functioning, Disability and Health [1] promotes the use of the terms “disability” and “impairment” to describe a multidimensional phenomenon arising from the interaction between individuals and their physical environment. However, it does not enforce a universal recommendation and acknowledges the importance of respecting people’s preferences in how they are addressed. Specifically, the term “Intellectual

and Developmental Disabilities” (IDD), introduced by the [2], formerly known as the American Association on Mental Retardation, has been proposed as a substitute for “intellectual disability” or “mental retardation.” Similarly, the American Psychiatric Association made a significant terminology update in the fifth edition of the Diagnostic and Statistical Manual (DSM-V) by replacing “mental retardation” with IDD to describe deficits in cognitive ability that originate during the developmental period. This change was a clear effort to align with the terminology already adopted by the WHO and the AAIDD. Following the recommendations of these prominent institutions in the field, the United Nations also

adopted the term “disability” in the text of the Convention on the Rights of Persons with Disabilities [3].

The population with IDD is characterized by deficits in intellectual and adaptive functioning, encompassing the conceptual, social, and practical domains. This classification is based on three specific criteria: (1) This includes difficulties in reasoning, problem-solving, planning, summarizing, thinking, judgment, school learning, and learning from experience. This criterion is supported by clinical assessment and standardized, individualized intelligence testing; (2) Individuals with IDD also exhibit challenges in one or more adaptive behaviours, impacting their ability to perform activities of daily living. These adaptive behaviours involve communication, social participation, and independent living in various environments, such as home, school, work, or the community; (3) The deficits in intellectual and adaptive functioning manifest before the age of 22 and are categorized as mild, moderate, severe, or profound, as identified by Schalock et al. [4]. People with IDD can experience particularly difficult situations when it comes to building and maintaining relationships, understanding social norms and communicating effectively with others [5]. Globally, the prevalence of individuals with IDD is approximately 1%, with a higher proportion observed in men than in women. Additionally, about 85% of IDD cases are classified as mild degree [6].

Physical activity and sedentary behaviour

A recently published systematic review highlighted that a staggering 91% of individuals with IDD fail to meet the Physical Activity Guidelines for Americans [7]. Individuals with IDD often exhibit high rates of sedentary behaviour and physical inactivity, primarily due to the barriers they encounter when attempting to engage in physical activity. A systematic review identified various perceived barriers to regular physical activity participation, classified into five main groups: personal (6 topics), family (4 topics), social (13 topics), financial (1 topic), and environmental (1 topic) as described by Jacinto et al. [8]. Knowing that regular physical activity is essential for health and quality of life, the barriers make it difficult for people with IDD to achieve these benefits. However, for individuals with IDD, it is recommended to engage in at least 150–300 min of moderate to vigorous physical activity per week or 75–150 min of vigorous intensity activity. Moreover, it is advised that they participate in muscle-strengthening activities involving the major muscle groups at moderate or higher intensity, at least twice a week. Following these recommendations can lead to significant health benefits and improve overall well-being for individuals with IDD [9].

Considering the lack of physical activity and a high prevalence of sedentary behaviours, individuals often exhibit unfavourable values of anthropometric (anthropometric variables are specific measurements that are used to assess the size, shape, and composition of the human body, e.g., height or weight) and body composition variables. While physical inactivity plays a significant role, variables like overweight and obesity can also be influenced by other factors, including an unhealthy diet, chronic energy imbalance, or side effects of medications. These unfavourable body composition values can give rise to various medical, emotional, or social issues directly or indirectly related to their disabling condition. Common problems include fatigue, pain, stigma, isolation, depression, anxiety, and other challenges associated with their circumstances. Likewise, all these factors promote an elevation in lipid profile variables (e.g., cholesterol or triglycerides), consequently escalating the risk of chronic diseases

[10]. Moreover, sedentary and inactive behaviour leads individuals with IDD to experience diminished levels of all physical capacities, significantly hindering their ability to perform activities of daily living and compromising their independence [11]. Several systematic reviews indicate that, when compared to the population without disabilities, individuals with IDD exhibit reduced levels of cardiorespiratory capacity [12] and muscular capacity [13] which may contribute to premature aging [14] and functional decline [15]. Overall, this not only leads to increased healthcare expenses but also diminishes their overall quality of life. Addressing these issues and promoting healthier lifestyles can have a positive impact on their overall well-being and quality of life [16].

Physical exercise

Engaging in regular exercise plays a fundamental role in preventing and modifying negative health effects and other risk factors associated with sedentary lifestyles and physical inactivity. It is considered a non-pharmacological strategy to promote physical capacities and quality of life. Exercise serves as an energy balancer and contributes to the regulation of body weight by increasing energy expenditure [17, 18]. Additionally, it enhances appetite control and reduces energy intake [19]. Furthermore, physical exercise serves as a crucial promoter of cardiorespiratory capacity and strength, significantly improving performance in activities of daily living [20–22]. By incorporating regular exercise into their routines, individuals can positively impact their overall health and well-being, counteracting the adverse effects of sedentary behaviour and physical inactivity.

Research on the effects of physical exercise in the population without disabilities has been extensive, but studies in the population with IDD are scarce [23], and their findings often do not reach statistical significance [24]. The studies present various methodological limitations, including small sample sizes, heterogeneity, non-randomized designs, and lack of effect size calculation [25–30]. Some reviews have examined the effectiveness of lifestyle interventions targeting changes in body weight and composition [31]. Although physical exercise programs have shown promise in reducing body mass and improving body composition, it is essential to consider that the intervention's overall effect may not be solely attributable to physical exercise. Furthermore, certain reviews have focused exclusively on one type of training, such as strength training or cardiorespiratory training [21, 32, 33]. However, considering a training regimen that incorporates both types of exercises may lead to more beneficial effects in individuals with IDD. More comprehensive and well-designed studies are needed to fully understand the potential benefits and optimize the impact of physical exercise interventions for this population. The research indicates that this type of exercise prescription yields substantial positive effects on various health parameters, including aerobic capacity, muscle strength, total cholesterol levels, and resting systolic blood pressure [34]. Furthermore, combined exercise programs have demonstrated their effectiveness as a therapeutic tool for enhancing functional capacity and promoting the transfer of improvements to activities of daily living [35]. By integrating these comprehensive exercise regimens into their routines, individuals with IDD can reap numerous health benefits and achieve an overall improvement in their quality of life. These exercise programs not only contribute to physical well-being but also foster greater independence and an enhanced ability to participate in daily activities, thereby promoting a more fulfilling and active lifestyle.

Traditionally, cardiorespiratory exercise programs are prescribed to improve cardiorespiratory capacity and strength exercise programs to improve this physical capacity. However, the types of training in isolation do not promote holistic physical condition improvement. Combined exercise programs involve the training of several physical capacities within the same training session. In this context, combined physical exercise programs, designed to enhance muscle strength, cardiorespiratory capacity, balance, and flexibility, have shown to positively impact various [36]. The Guidelines for Exercise Testing and Prescription for individuals with IDD [36] recommend incorporating aerobic, resistance, and flexibility training into combined exercise programs. Specifically, aerobic exercise focuses on the circulatory and respiratory system's ability to supply oxygen during sustained physical activity, resistance training targets muscle strength, and flexibility training aims to improve the range of motion at joints. Research suggests that this type of exercise prescription has significant positive effects on aerobic capacity, muscle strength, total cholesterol levels, and resting systolic blood pressure [34]. Moreover, combined exercise programs have proven to be an effective therapeutic tool for enhancing functional capacity and its transfer to activities of daily living [35].

Currently study

In order to draw robust conclusions about the effects of exercise interventions and offer valuable insights for future studies and field interventions, it is crucial that systematic reviews are based on high-quality randomized controlled trials, which aim to minimize bias and provide accurate estimates of intervention effect sizes [37]. Therefore, the primary objective of this systematic review with meta-analysis is to evaluate the literature of published, peer-reviewed clinical trials involving combined exercise interventions and assess their effects on individuals with IDD. Our hypothesis is that combined exercise, when conducted independently without any other associated intervention in the same session, will have significant effects in individuals with IDD. Additionally, we aim to achieve secondary objectives, such as summarizing the characteristics of the studies, including their design, participant details, and the frequency, intensity, time, and type (FITT [36]) characteristics of the interventions. Furthermore, we intend to evaluate the risk of bias present in the included studies and provide recommendations to enhance the quality of future research and exercise prescription in this population. By conducting this review, we aim to contribute valuable information to advance the understanding and implementation of exercise interventions for individuals with IDD.

Methods

This systematic review followed the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) as outlined by Page et al. [38]. The review was conducted between June and July 2023 and was registered in PROSPERO with the registration number CRD42023438822. The review utilized the PICOS strategy [39, 40] which entailed the following components: (i) "P" (Patients) Participants with IDD of all ages, regardless of gender, race, and ethnicity.; (ii) "I" (Intervention) Any combined training program conducted in the same session with individuals with IDD, including those with Down Syndrome, regardless of the intervention duration; (iii) "C" (Comparison) The review compared the outcomes of the intervention group with those of the control

group; (iv) "O" (Outcome) The primary or secondary variable under study was the effectiveness of the combined training program; (v) "S" (Study Design) The review included randomized controlled clinical trials.

Eligibility criteria

Eligible studies examining the effects of combined training interventions on individuals with IDD had to meet the following inclusion criteria: (i) Randomized controlled studies; (ii) Intervention studies with any duration; (iii) Population with IDD, irrespective of race, ethnicity, gender, or age group; (iv) Studies with any number of participants; (v) Intervention programs consisting of combined physical exercise in the same session. Conversely, studies with the following characteristics were excluded: (i) Studies not written in English; (ii) Papers with participants having different types of disabilities or pathologies; (iii) Papers lacking a clear description of the intervention protocol; (iv) Papers involving interventions that were not solely focused on combined training within the same group (e.g., interventions combining training with nutrition, education for healthy lifestyles, and others).

Information sources and research strategies

In June 2023, electronic searches were conducted in several databases, including PubMed (title and abstract), Web of Science, Scopus, and SPORTDiscus (title/abstract/keywords). The search encompassed articles published up until June 15, 2023. To enhance the research, a combination of Medical Subject Headings descriptors and natural language terms [41] were used, namely: "aerobic exercise," "aerobic training," "cardio training," "cardiorespiratory training," "cardiorespiratory exercise," "cardio exercise," "cardio training," "cardiorespiratory exercise," "cardiorespiratory exercise," "continuous exercise," "continuous training," "high-intensity interval training," "HIIT," "interval training," "interval exercise," "endurance exercise," "endurance training," "resistance exercise," "resistance training," "strength training," "neuromuscular training," "resistance exercise," "strength exercise," "neuromuscular exercise," "flexibility exercise," "flexibility training," "combined training," "combined exercise," "multi-component," "multi-component," "concurrent training," "concurrent exercise," "mental retardation," "intellectual disability," "intellectual disabilities," "intellectual and developmental disabilities" and "down syndrome," as indicated in Table 1.

Table 1. Research strategy.

Search number	Research content
1	("aerobic exercise" OR "aerobic training" OR "cardio training" OR "cardiorespiratory training" OR "cardiorespiratory training" OR "cardio exercise" OR "cardio training" OR "cardiorespiratory exercise" OR "cardiorespiratory exercise" OR "continuous exercise" OR "continuous training" OR "high-intensity interval training" OR HIIT OR "interval training" OR "interval exercise" OR "endurance exercise" OR "endurance training" OR "resistance exercise" OR "resistance training" OR "strength training" OR "neuromuscular exercise" OR "flexibility exercise" OR "flexibility training" OR "combined training" OR "combined exercise" OR "multi-component" OR "multi-component" OR "concurrent training" OR "concurrent exercise") AND ("mental retardation" OR "intellectual disability" OR "intellectual disabilities" OR "intellectual and developmental disabilities" OR "down syndrome")

Selection and data collection process

The aim of this research was to identify intervention studies based on combined training programs, irrespective of their specific purpose. Two authors (MJ and SD) independently conducted the search, and after removing duplicate articles and reviewing the titles and abstracts according to the eligibility criteria, the results were compared and discussed. In instances where discrepancies arose between the two authors, a third author (RA) was available to collaborate and reach a final decision. One of the authors (MJ) was responsible for extracting essential information from the articles, including authors' names, year of publication, country of origin, study objectives, participant details, intervention duration/frequency, exercises/intensities employed, and outcome measurements used.

Quality of study and risk of bias

The assessment of each study's quality and the evaluation of potential biases were conducted using the Cochrane Collaboration Risk of Bias Tool [42]. Two reviewers independently assessed the quality of the studies, and in cases where discrepancies emerged between the reviewers, a third investigator (RA) was involved to perform the analysis and facilitate discussion with the first two investigators to reach a consensus.

GRADE assessment

The Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) approach was utilized to assess the strength of the evidence using GRADEpro [43]. The certainty of evidence for each outcome was categorized as very low, low, moderate, or high. This judgment was based on five downgrading factors (risk of bias, indirectness, inconsistency, imprecision, and publication bias) and three upgrading factors (large effect size, dose-response relationship, and opposing plausible residual bias and confounding). Two reviewers independently assessed the strength of the evidence for each study, and any differences between them were resolved through discussions or, if necessary, by involving a third investigator.

Data analysis

The meta-analysis adhered to the guidelines outlined in the Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols by Moher et al. [44]. Comprehensive Meta-analysis Version 3.0 statistical software (Biostat, Inc., Englewood, CO, USA) was employed for conducting the meta-analysis. The standard difference in means was calculated using relevant data from the primary manuscripts, including pre- and post-intervention means, standard deviations, and the number of participants. In cases where this information was not directly presented in the studies, the Cochrane handbook's recommended procedures by Higgins et al. [42] were followed to estimate these values. Effect sizes were measured using the randomized effects model, with a 95% confidence interval (CI), magnitude effects, and assessment of statistical significance ($p < 0.05$). To assess the influence of individual studies on the overall effect size, a sensitivity analysis was performed using the leave-one-out method, where each study was excluded one at a time, and the analysis was repeated [45]. Heterogeneity among studies was evaluated using the following statistics: τ^2 , χ^2 , and I^2 value was used to classify heterogeneity

as follows: less than 50% represented low heterogeneity, 50–74% indicated substantial heterogeneity, and 75% or higher denoted considerable heterogeneity [46]. The funnel plot's asymmetry was assessed using [47] method to verify the presence of publication bias. An inverted funnel-shaped plot indicated no publication bias [48]. Effect sizes of the standard means differences were classified using Cohen's categories: d values between 0.2 and 0.5 were considered a small effect size, between 0.5 and 0.8 represented a medium effect size, and values greater than 0.8 indicated a large effect size [49].

Results

A comprehensive search of the databases yielded a total of 626 studies. After the initial screening phase, which involved reviewing titles and abstracts, 33 studies were identified as potentially eligible to the study. Subsequently, applying the pre-defined eligibility criteria and conducting a thorough review of the full-text articles, eight studies were found to meet the eligibility criteria and were included in this systematic review for detailed analysis (please refer to Figure 1).

In this systematic review, eight intervention studies examining combined training programs in individuals with IDD were analysed. The studies encompassed various populations, including those with Down syndrome, and evaluated the effects of exercise on physical fitness, body composition, muscle strength, and functional mobility. The results demonstrated overall positive effects of the interventions on multiple outcome measures, supporting the potential benefits of combined training programs for individuals with IDD. See Table 2 for details.

Quality of studies and risk of bias

Among the included studies, five demonstrated a low risk of bias in random sequence generation, while three had an unclear risk for this item. Regarding allocation concealment, three studies were deemed to have a low risk of bias, while five studies had an unclear risk. For blinding of participants and personnel, two studies had a low risk, five had an unclear risk, and one study was classified as high risk. As for blinding of the outcome assessment, two studies were considered low risk, and six were classified as unclear risk. All studies were assessed as having a low risk of bias for incomplete outcome data. In terms of selective reporting and other biases, six studies were categorized as low risk, while one study had an unclear risk. See Figure 2 and 3 for detailed information.

Effects of combined training on anthropometric measures/body composition

Although the effect of combined exercise on anthropometric measures/body composition variables in individuals with IDD was not statistically significant and showed a small effect (SMD = -0.16 ; 95% CI, -0.34 to 0.03 ; $Z = 1.68$; $p = 0.09$), it is important to note that the confidence interval includes zero, indicating that there is no significant difference from zero in the true standard difference in means. Additionally, there was no observed heterogeneity ($I^2 < 50\%$, $p > 0.05$). The smaller studies appearing towards the bottom of the graph exhibited greater variability in effect size estimates due to sampling variation, leading to a dispersed distribution of values (see Figures 4 and 5).

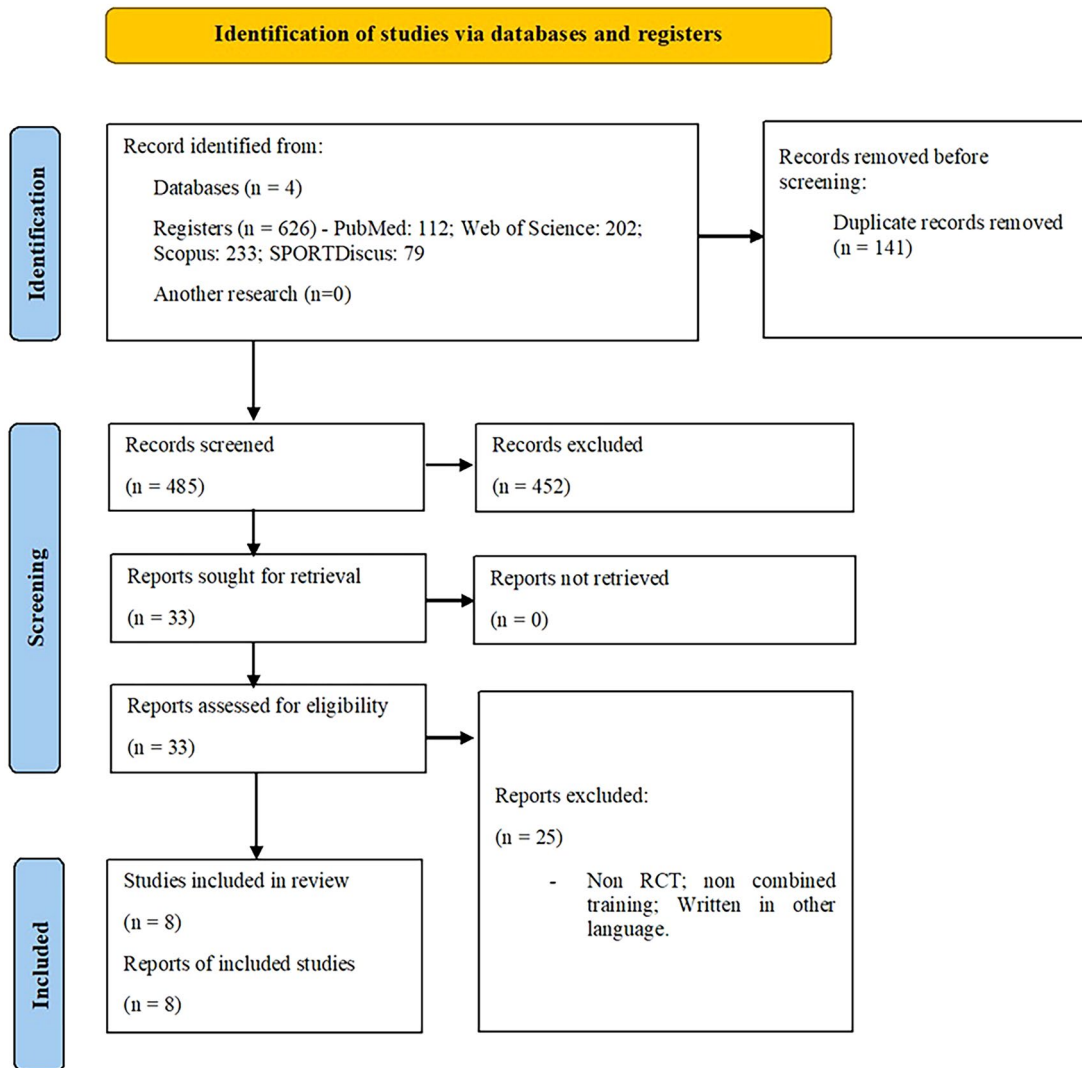


Figure 1. PRISMA flow diagram illustrating each phase of the search and selecting process.

Effects of combined training on lipid profile

Combined exercise demonstrated a residual effect size that is not statistically significant, leading to the acceptance of the null hypothesis (SMD = -0.07; 95% CI, -0.43 to 0.29; $Z=0.38$; $p=0.71$). As the confidence interval includes zero, it indicates that the true standard difference in means is not significantly different from zero. No heterogeneity was observed ($I^2 < 50\%$, $p > 0.05$). Like the previous funnel plot for anthropometric measures/body composition variables, the studies appearing towards the bottom of the graph in this plot are smaller studies and exhibit greater dispersion of values due to increased sampling variation in the effect size estimates (see Figures 6 and 7).

Effects of combined training on functional capacity

Combined exercise appears to have a positive impact on functional capacity variables in individuals with IDD, showing a small effect size, and thus, the null hypothesis should be rejected (SMD = 0.28; 95% CI, 0.01 to 0.54; $Z=2.03$; $p=0.04$). The confidence interval does not include zero, indicating that the true standard difference in means is indeed different from zero. However, substantial heterogeneity was observed ($I^2 = 50\%$, $p \geq 0.01$).

Additionally, there may be a presence of publication bias as the studies do not seem to be symmetrically distributed concerning the combined effect size (see Figures 8 and 9).

Effects of combined training on cardiorespiratory capacity

Combined exercise appears to significantly improve cardiorespiratory capacity in individuals with IDD, showing a medium effect size, leading to the rejection of the null hypothesis (SMD = 0.80; 95% CI, 0.34 to 1.26; $Z=3.41$; $p \leq 0.001$). The confidence interval does not include zero, indicating that the true standard difference in means is indeed different from zero. However, considerable heterogeneity was observed ($I^2 = 90\%$, $p \leq 0.001$). Additionally, there may be a presence of publication bias, as the studies do not seem to be symmetrically distributed concerning the combined effect size (see Figures 10 and 11).

Effects of combined training on strength capacity

Combined exercise appears to significantly improve strength capacity in individuals with IDD, exhibiting a medium effect size, leading to the rejection of the null hypothesis (SMD = 0.77; 95% CI, 0.45 to 1.08; $Z=4.78$; $p \leq 0.001$). The confidence interval does not include

Table 2. Study characteristics.

Studies	Aims	Participants	Duration/ frequency	Exercise/intensity	Measurements
Elmahgoub et al. [50], Belgium, Europe.	Influence of combined exercise training on indices of obesity, physical fitness and lipid profile.	N=30 (no reference to sex); 14 – 22y; Mental retardation (IQ: 45 and 70); Randomised groups: intervention group (N=15) and control group (N=15); No sample size calculation.	10 weeks; 3 x week; 50 min/session.	Warm up (5 min), cycling (10 min), strength training of the biceps brachii and triceps brachii (10 min), stepping (10 min), strength training of the quadriceps and hamstrings (10 min) and cooling down (5 min); Aerobic training (cycling and stepping: 60%–75% peak heart rate); Strength exercises were performed using stack weight equipment (60%–80% of one repetition maximum (1RM)); 3 series; 10 repetitions; Between two sets, a resting period of 60 s was minded; No mention is made of the minimum percentage of attendance to the sessions to be part of the exercise group.	Body weight – digital balance scale (Seca, max, 200kg, Germany); Height – stadiometer (Holtain Ltd., UK); BMI (kg/m ²); Waist circumference – tape; Body composition was assessed by bio-impedance (Bodystat 1500 MDD); Fat mass and fat-free mass were calculated using the formula (Fat-free mass = total body water/0.732 (28) and fat mass = body weight – Fat-free mass); Blood samples (high-density lipoprotein-C and Low-density lipoprotein (PEG + cholesterol-oxidase; Roche Diagnostics), triglycerides (glycerol phosphate—PAP; Roche Diagnostics) and total cholesterol (cholesterol-oxidase/PAP; Roche Diagnostics); Maximal cardiopulmonary exercise test; Six-minute walk test; One-repetition maximum (for biceps brachii, triceps brachii, quadriceps and hamstrings); Functional sit-to-stand test; Hand grip strength; Muscle fatigue resistance.
González-Agüero et al. [51], Spain, Europe.	Determine whether youths with Down syndrome are able to increase lean mass and decrease fat mass, after exercise.	N=25 (13 females and 13 males); 10 – 19y; Down's syndrome (no reference to IQ); Randomised groups: intervention group (N=13) and control group (N=12); No sample size calculation.	21 weeks; 2 x week; Min/session: not mentioned.	The training consisted of 1 or 2 rotations in a circuit of 4 stages: Jumps, Press-ups on the Wall, Elastic-fitness bands, Adapted-medicine balls; Four fitness bands of increasing resistance colors and four medicine balls were used, each assigned to a group depending on the strength required to perform the exercises. Each group followed the same exercise program with a different color band and ball; Weeks 1–5: 1 set: 10 reps; Weeks 6–10: 2 sets: 10 reps; Weeks 11–15: 2 sets: 15 reps; and Weeks 16–21: 2 sets: 20 reps; A minimum attendance of 70% was required to be included in the exercise group.	Height; Weight; Body mass index – weight (kg) divided by height squared (m ²); Pubertal development; whole-body scan by dual energy X-ray absorptiometry.
Gupta et al. [52], India, Asia.	Effect of exercise training on strength and balance in children.	N=23 (9 females and 14 males); 7 – 15y; Down's syndrome (IQ: 36–52); Randomised groups: intervention group (N=12) and control group (N=11). No sample size calculation.	6 weeks; 3 x week; Min/session: not mentioned.	Strength training was started at 50% of 1RM; Resistance exercises using sandbags were given for hip flexors, abductors, extensors, knee flexors and extensors and ankle plantarflexor; 2 series; 10 reps; resistance was increased by half a kilogramme (1,1 lbs) when the child was able to complete the sets with ease and without undue stress; Balance training: horizontal jumps, vertical jumps, one leg stance with eye open, tandem stance, walking on line, walking on balance beam and jumping on a trampoline; 10 reps; it was increased by five repetitions when the child was able to do it with ease; No mention is made of the minimum percentage of attendance to the sessions to be part of the exercise group.	Height was measured with the shoes removed using a metal tape measure, Weighing scale was used to measure the weight; Handheld dynamometer (hip flexors, hip abductors, hip extensors, knee flexors, knee extensors and ankle plantarflexors); balance subscale of Bruininks Oseretsky Test of Motor Proficiency.
Ko et al. [53], South Korea, Asia.	Effects of physical activity on the muscular strength of the lower extremities.	N=20 (no reference to sex); 7 – 15y; IDD (no reference to IQ); Randomised groups: intervention group (N=10; 45.2±2.5y) and control group (N=10; 49.8±3y); No sample size calculation.	24 weeks; 3–4 x week; 60 min/session.	Aerobic exercise and muscular strengthening exercise; 55–69% HRmax; No mention is made of the minimum percentage of attendance to the sessions to be part of the exercise group.	Muscular strength of the flexors and the extensors of the knee joint (isokinetic device (Cyber 770, USA).

(Continued)

Table 2. Continued.

Studies	Aims	Participants	Duration/ frequency	Exercise/intensity	Measurements
Rimmer et al. [54], Chicago, USA.	Effectiveness of an exercise training program.	N=52 (29 females and 23 males); 39.4 ± 6.4 y; Down's syndrome (no reference to IQ); Randomised groups: intervention group (N=30) and control group (N=22). The sample size was selected based on an alpha level of 0.05 and a minimum desired power of 0.80. A simulation model was created using the statistical package PASS 2000 (Kaysville, UT) to detect a 5% to 10% mean difference between the groups. With 30 and 22 participants in the groups, small statistical power was guaranteed.	12 weeks; 3 x week; 45 min/session,	30 to 45 min of cardiovascular exercise and 15 to 20 min of muscular strength and endurance; Cardiovascular exercise: recumbent stepper, stationary cycle (recumbent and upright), treadmill, and elliptical cross-trainer (50% to 70% peak VO ₂); Strength and endurance exercise: 70%- 80% of the participants' 1-RM for 1 set of 10 to 20 reps (equipment: bench press, seated leg press, seated leg curl, triceps push-down, seated shoulder press, seated row, lat pull-down, and biceps curl); No mention is made of the minimum percentage of attendance to the sessions to be part of the exercise group.	Peak oxygen uptake; 1-RM (bench press and seated leg press machines); Handgrip strength - Grip-A handgrip dynamometer (Tokyo, Japan); Height, weight, and skinfold measure; Body Mass Index.
Silva et al. [55], Portugal, Europe.	Effects of a Wii-based exercise program on physical fitness, functional mobility and motor proficiency.	N=25 (no reference to sex); 18 – 60 y; Down's syndrome (no reference to IQ); Randomised groups: intervention group (N=12) and control group (N=13); No sample size calculation.	8 weeks; 3 x week; 60 min/session.	Individual or paired game-like physical exercises by a virtual reality system (Wii Fit Balance), including aerobic endurance, balance and isometric strength; No mention is made of the minimum percentage of attendance to the sessions to be part of the exercise group.	Height - stadiometer with a 0,1-cm accuracy; Waist circumference - steel anthropometric tape; Weight, body mass index (BMI), body fat percentage, visceral fat levels and muscle mass - segmental body composition analyser (Tanita BC 531); Eurofit Test Battery; Bruininks–Oseretsky Test of Motor Proficiency First Edition; Timed Up & Go Test.
Sun et al. [56], China, Asia.	Adapted physical activity intervention on health-related physical fitness.	N=57 (no reference to sex); 12 – 18 y; IDD (IQ: 35–69); Randomised groups: intervention group (N=39) and control group (N=18); No sample size calculation.	8 weeks; 2–3 x week; 45 min/session.	Strength and endurance exercise: 30% to 60% maximal heart rate reserve; The authors only report that attendance was high.	Cardiorespiratory fitness – 9-min run/walk test; Muscular strength and endurance - handgrip strength test and 30-s sit-ups; Flexibility - Sit-and-reach test.
Tamin et al. [57], Indonesia, Asia.	Effectiveness of endurance exercise to increase physical fitness.	N=212 (74 females and 138 men's); 10 – 30 y; IDD (IQ: mild to severe); Randomised groups: group I (N=68; lower extremity muscles endurance exercise for 20 RM followed by a cardiorespiratory endurance exercise for 24–25 min), group II (N=74; a lower extremity muscles endurance exercise for 10 RM followed by a cardiorespiratory endurance exercise for 26–27 min) and control group (N=70); Sample size was determined based on a single sample calculation for mean difference analytical study, minimum sample coupled with the possibility of dropouts was 174 subjects.	16 weeks; 3 x week; 45 min/session.	Group I: Lower extremity muscles endurance exercise: 1–3 series; 50%–100% 20RM; cardiorespiratory endurance exercise: 24–25 min duration; Group II: Lower extremity muscles endurance exercise: 1–3 series; 50%–100% 10RM; 26–27-minute duration. No mention is made of the minimum percentage of attendance to the sessions to be part of the exercise group.	10 repetition maximum (RM); cardiorespiratory endurance level with six minutes walking test on rectangular track.

Note: IDD, Intellectual and Developmental Disabilities; IQ, intelligent quotient; Min, minutes; N, sample; y, years.

zero, indicating that the true standard difference in means is indeed different from zero. However, substantial heterogeneity was observed ($I^2 = 72\%$, $p \leq 0.001$). Additionally, there may be a presence of publication bias, as the studies do not seem to be symmetrically distributed concerning the combined effect size (Figures 12 and 13).

Certainty of evidence

We employed the GRADE framework to assess the certainty of evidence in this study. Due to methodological limitations in the

included studies, the certainty of evidence in the meta-analysis was rated as low to very low. Limitations related to “study design” led to a downgrade in the certainty of evidence, along with considerations for “risk of bias” and “publication bias” based on funnel plot asymmetry in some meta-analyses. Imprecision was also a factor, with certain meta-analyses receiving low ratings due to potential clinical decisions being influenced by the range of confidence intervals. Moreover, “indirectness” was considered as substantial differences in populations, interventions, and outcomes between the review question and the included studies affected the certainty of evidence in all meta-analyses. For “inconsistency,” similarities in point estimates and confidence interval overlaps, as well as statistical criteria for meta-analysis heterogeneity, led to a downgrade of one or two levels of certainty in certain meta-analyses. No upgrades were made in any meta-analysis as no large effect sizes were found, and the study only included randomized controlled trials, thereby not warranting any upgrades based on the dose-response relationship or plausible confounding.

Characteristics of intervention

Participants

The total number of participants included in these studies was 444, with 273 in the exercise groups and 171 in the control groups. Participants ranged from children to adolescents and adults, and among the eight selected studies, four focused on the Down syndrome population. The selected studies for this systematic review with meta-analysis were published in diverse geographical areas, including one from the American continent [54], three from Europe [50, 51, 55] and four from the Asian continent [52, 53, 56, 57]. Notably, half of the studies were published in Asia. Regarding the intelligence quotient, four studies did not report the range [51, 53–55], one study mentioned that participants fell within the mild to severe range [57] while three other studies reported participants classified with an intelligence quotient between 35 and 70 [50, 52, 56].

Structure (duration/frequency) and training protocols

The duration of the intervention programs in the selected studies had an average of 13 weeks, ranging from 6 to 24 weeks, with no consistent pattern. Weekly frequency also varied between 2 and 3 sessions per week, with 3 sessions per week being the most

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Elmahgoub et al. (2009)	+	+	+	+	+	?	?
González-Agüero et al. (2011)	?	?	?	?	+	+	+
Gupta et al. (2011)	+	?	?	?	+	+	+
Ko et al. (2012)	?	?	?	?	+	+	+
Rimmer et al. (2004)	+	?	-	?	+	+	+
Silva et al. (2017)	+	+	?	?	+	+	+
Sun et al. (2022)	+	+	+	+	+	+	+
Tamin et al. (2015)	?	?	?	?	+	+	+

Figure 2. Risk of bias summary.

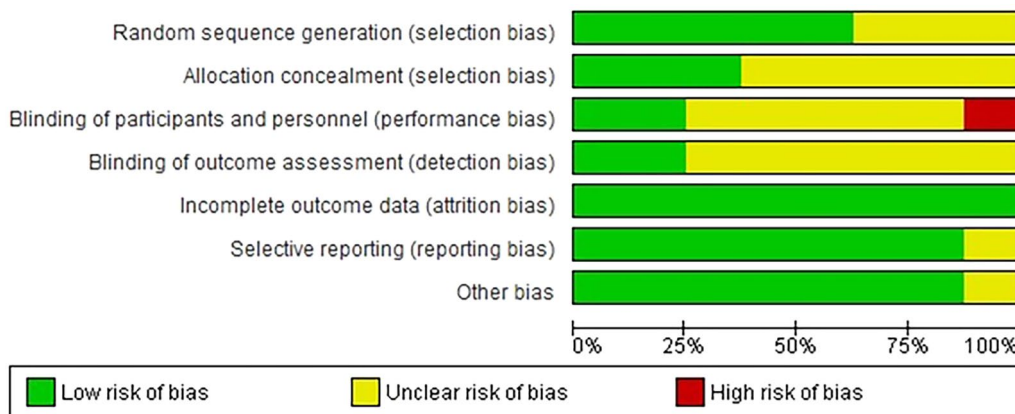


Figure 3. Risk of bias graph.

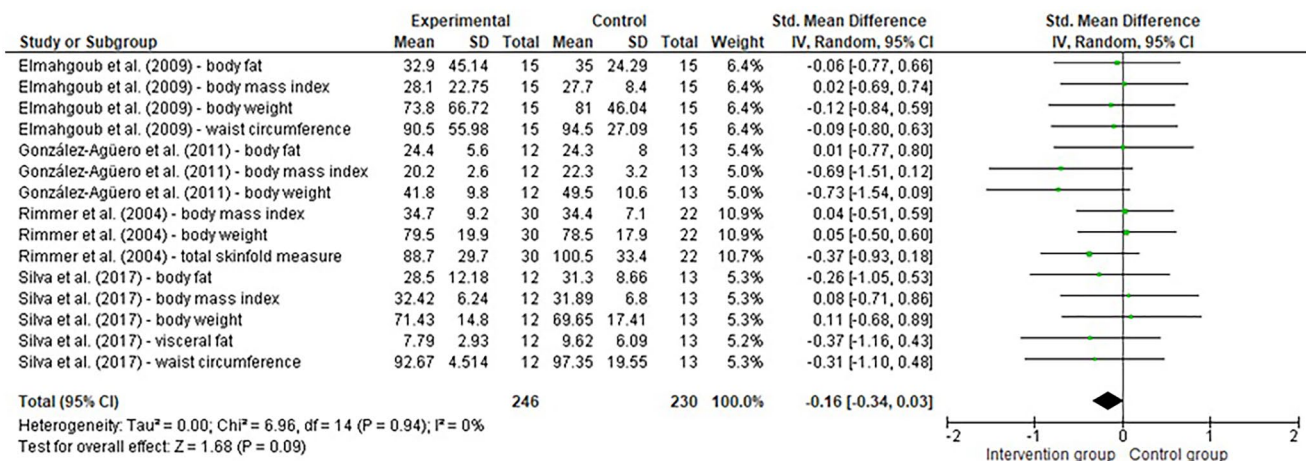


Figure 4. Forest plots showing the effects of combined exercise on anthropometric measures/body composition.
Note: SD, Standard Deviation; CI: Confidence Interval; IV, Inverse Variance.

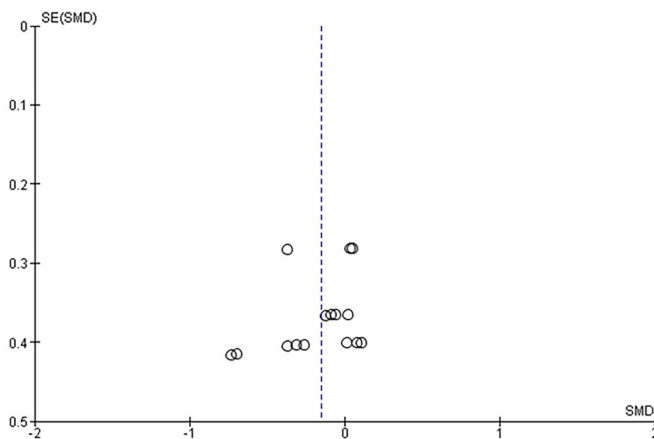


Figure 5. Funnel plot of publication bias of anthropometric measures/body composition variables.

common. Regarding the duration of each session, two studies did not provide specific information [51, 52], while the other studies prescribed session durations between 45 and 60 min. The assessment and intervention protocols adopted differed among the studies, lacking standardization across the literature.

Discussion

The objective of this systematic review with meta-analysis is to evaluate the effects of combined exercise interventions in individuals with IDD, based on published, peer-reviewed clinical trials. Out of the numerous studies assessed, eight randomized controlled trials met the eligibility criteria for inclusion in this review. The main finding indicates that physical exercise has effects on all analysed variables, although some may not be statistically significant. This partially supports our hypothesis, aligning with findings from studies involving participants without disabilities [58, 59].

Prescription

While the studies in this review adhere to the FITT model [36], the temporal heterogeneity makes it challenging to draw definitive

conclusions about the effects of interventions over shorter or longer durations on various components of physical fitness. Nevertheless, a systematic review with meta-analysis focusing on this population indicated that short-term exercise programs were more effective than longer ones, and exercise frequency of 4 times a week showed better results than 3 times a week in anthropometric, body composition, and physical fitness variables [30]. This discrepancy in findings may be related to differences in participants' motivation and adherence to the prescribed exercise programs [8]. The variability in assessment and intervention protocols also adds to the heterogeneity, limiting the ability to draw robust conclusions in this regard.

Anthropometric measures/body composition

Although our study's results indicate a potential trend towards a reduction in anthropometric measures/body composition (SMD = -0.16), they are not statistically significant ($p = 0.09$). Due to the scarcity of studies in the literature, as in the present meta-analysis, most meta-analyses include several variables in the same dimension and do not analyse subgroups by variable. Shin and Park [30], for biometric and body composition variables, state that the effects are unclear. Kapsal et al. [28] showed a moderate effect of physical exercise on the health outcomes for youth with IDD ($g = 0.743$, $p < .001$). However, in addition to encompassing all types of exercise, these health outcomes correspond to several variables beyond anthropometric measures/body composition, namely cardiorespiratory capacity, muscular strength, blood pressure, cholesterol, functional capacity (e.g., activities of daily living), or reaction time.

Recently, Salse-Batán et al. [60] carried out a meta-analysis, where they analysed the effect for each variable of interest, for each type of training and a sub-group analysis by age group. In addition to the results not being significant, some analyses were performed with a very small number of studies and included a study that is not a true randomized controlled trials because it was not possible to perform strict randomization of the participants, so the results should be taken with caution. Regarding body mass, BMI, fat mass and waist circumference in children, adolescents and adults no significant results for cardiovascular training, combined training or other type of exercise [60]. Following the results presented above, small effect size for weight, SMD = 0.13, 95% CI [-0.12, 0.37] and inconsistent for waist circumference 95% CI [-0.37,

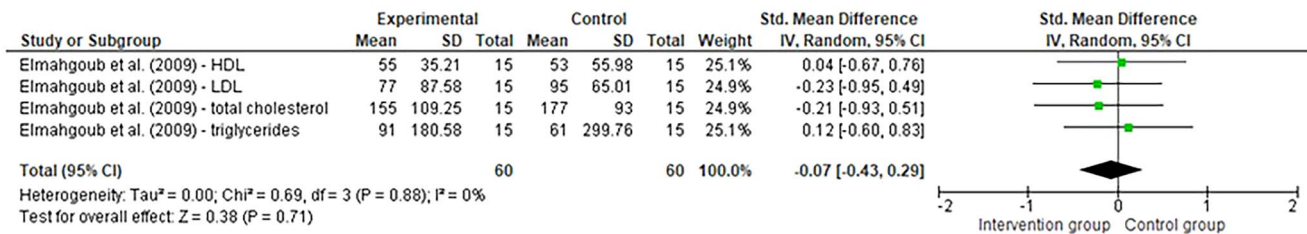


Figure 6. Forest plots showing the effects of combined exercise on lipid profile.
Note: SD, Standard Deviation; CI: Confidence Interval; IV, Inverse Variance.

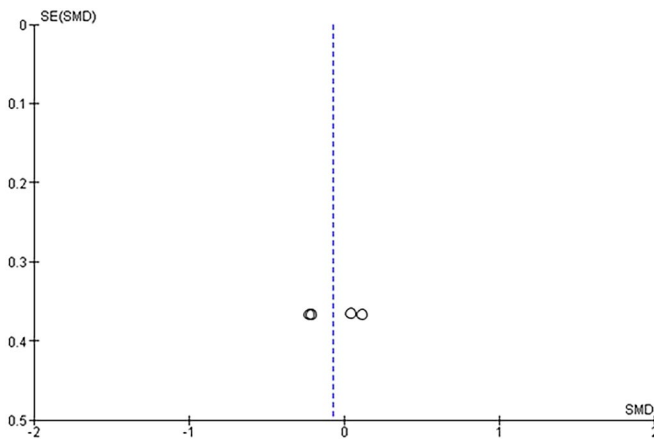


Figure 7. Funnel plot of publication bias of lipid profile.

0.50] were found by St. John et al. [61], however, the author also analysed all types of exercise together.

On the other hand, studies in the population without disabilities are also unclear and inconclusive. However, studies state that combined strength and cardiorespiratory exercise training seems to be good strategy to increase fat-free mass and reduce fat mass, being the best method to lose weight and fat mass and maintain fat-free mass [62, 63]. In the opposite direction, if the focus is only on reducing body mass, aerobic training seems to be the most effective [60, 64]. Among the various types of cardiorespiratory training, interval training seems to be the one with also the greatest effect [65]. Previous studies seem to indicate that physical exercise alone does not produce significant changes in anthropometric measures/body composition variables [24, 66]. In this sense, the literature suggests that individuals with IDD should maintain a healthy diet and reduce caloric intake while increasing energy expenditure, creating a negative balance, enhancing body composition variables [67, 68].

On the other hand, weight loss and body composition improved in individuals with IDD by the prescribed medication, which may be one of the factors for the meta-analysis not being significant. A large proportion of this population are prescribed antipsychotic and antidepressant medications [69], potentially causing the side effect of weight gain [70], and this medication-induced weight gain is significant and often difficult to reverse. Finally, as previously mentioned, although the prescription of the studies followed the FITT model and the American College of Sports Medicine [36] guidelines, it may not have been sufficient for the results to be significant.

Lipid profile

As with the anthropometric measures/body composition variables, combined exercise has a residual effect size (SMD = -0.07

and is not significant ($p=0.71$) for the reduction of lipid profile variables and the confidence interval included zero. However physical exercise, namely combined training, has already shown significant effects on the variables in focus in individuals with IDD. Calders et al. [34], when prescribing a combined exercise program, found a significant difference in cholesterol variables. Participants trained twice a week for 70 min per session. The training included muscle strengthening of the biceps brachii, triceps brachii, quadriceps, hamstrings, abs and dorsalis, cycling, step and running. Cardiorespiratory training was performed at intensity 90% of the anaerobic ventilatory threshold, which increased to 100% after 10 sessions and to 110% after 20 sessions and the participants used stationary bikes, cross trainers, and a treadmill.

In a meta-analysis where the effect size was analysed with all types of training together, St. John et al. [61] reported a medium effect, SMD = 0.30, 95% CI [0.56, 0.03] for the variable blood pressure. Kapsal et al. [28] also stated that exercise significantly promotes health outcomes ($g=0.743$, $p<.001$). In addition to encompassing all types of exercise, it refers to health outcomes as anthropometric measures/body composition, namely cardiorespiratory capacity, muscular strength, functional capacity (e.g., activities of daily living), or reaction time, also encompassing variables such as blood pressure and cholesterol.

For the health children and adolescents the results of meta-analysis showed that combined exercise was superior to cardiorespiratory training in terms of LDL cholesterol (MD = -10.20 mg/dL, 95% CI -17.97 to -2.43; $p=0.01$; $I^2=30.8\%$; SMD = -0.35) [71]. As mentioned above, the prescription performed may not have been sufficient for the results to be significant, despite following the FITT model and American College of Sports Medicine guidelines (2021). As an example, Cugusi and Carta [72] despite observing a reduction in some of these variables, they were not statistically significant, suggesting that studies with longer interventions are needed to identify significant effects.

Although the mechanisms behind the effect of exercise on lipid profile are unclear, exercise appears to increase the ability of skeletal muscles to utilize lipids as opposed to glycogen, therefore reducing plasma lipid levels [73, 74].

Functional capacity

Contrary to anthropometric measures/body composition variables and lipid profile, combined exercise seems to improve functional capacity variables in individuals with IDD, with the confidence interval almost touching zero. Previous studies have found no significant differences in some variables in functional capacity by implementing a strength program. The results of Sugimoto et al. [75] showed a small, statistically non-significant effect (SE: 0.11, 95% CIs: -0.47, 0.69, $p=0.71$, Figure 5), of the

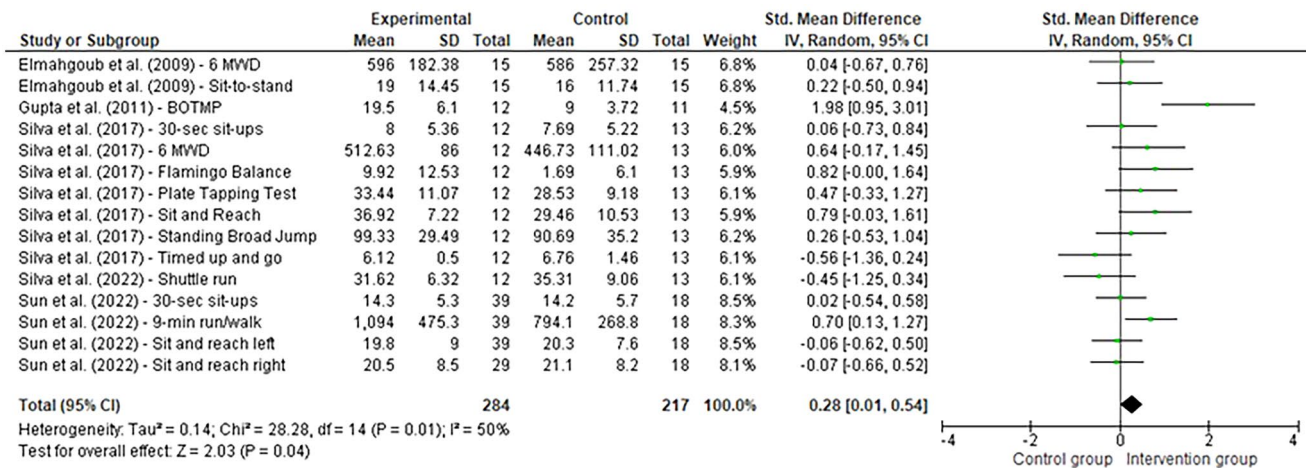


Figure 8. Forest r

Note: SD, Standard Deviation; CI: Confidence Interval; IV, Inverse Variance.

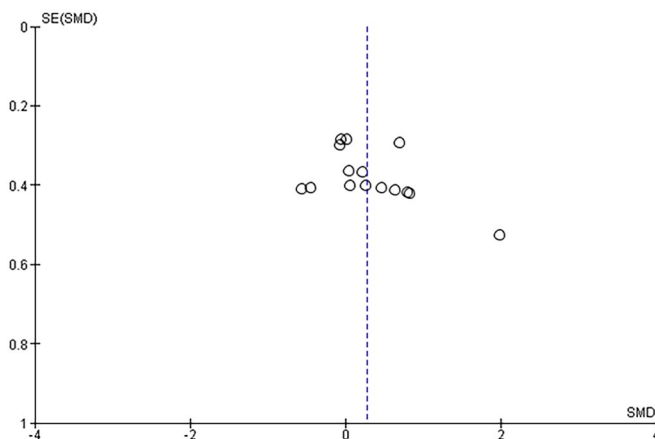


Figure 9. Funnel plot of publication bias of functional capacity.

intervention on grocery shelving (functional mobility task). The SE of effect sizes from the same two studies demonstrated a small, statistically non-significant effect (SE: 0.25, 95% CIs: -0.34, 0.83, $p=0.41$, Figure 6), of the intervention on timed up-and-down stairs [75]. On the other hand, Obrusnikova et al. [33] showed a statistically significant effect of the strength training on the 6MWT (SMD = 0.48; 95% CI = 0.14 to 0.83; $z=2.79$; $p=.005$), with higher effect size than we found. A meta-analysis analysed studies with different types of exercise, significant effects were found on 6-min walk distance (51.86 m, 95% CI [16.49, 87.22], $p < .05$) [76].

For populations with other comorbidities, including after stroke disease combined exercise had a significantly increased functional capacity (mean ES = .45, 95% CI = .25 to 0.65, $p < .0001$) [77]. Also in older people, combined training seems to be the best strategy to improve functional capacity [78].

Our systematic review with meta-analysis seems to indicate a fundamental role of combined physical exercise in increasing mobility/functionality, which contributes to preventing the onset of functional decline, independence, and quality of life in individuals with IDD.

Cardiorespiratory capacity

Combined exercise seems improve cardiorespiratory capacity in individuals with IDD, and the confidence interval is far from zero.

As previously mentioned, in a meta-analysis where effect size was analysed with all types of training together, St. John et al. [61] indicated a medium effect (SMD = 0.55) when comparing the exercise intervention to the sedentary control; 95% CI [0.17, 0.94]. On the other hand, despite focusing only on cardiorespiratory capacity variables, Obrusnikova et al. [33] showed that combined interventions (resistance, balance, and/or flexibility exercises) reported slightly more effective (SMD = 0.40; 95% CI = 0.11 to 0.70; $z=2.69$; $p=.007$) than the non-combined interventions (SMD = 0.42; 95% CI = 0.05 to 0.79; $z=2.25$; $p=.02$). Nevertheless, our meta-analysis demonstrated a larger effect size compared to the studies presented.

Another meta-analysis, where the authors referred to physiological measures (variables such as strength or cardiorespiratory capacity), evidenced a medium effect sizes (i.e., effect sizes .3–.8) to large effect (i.e., effect sizes larger than 0.8) analysing all types of training together [30].

For populations with other comorbidities, namely after stroke disease or with heart failure, combined exercise significantly increased cardiorespiratory capacity (mean ES = .41, 95% CI = .25 to .56, $p < .0001$; SMD = 0.77, 95% CI 0.39–1.14, $I^2 = 80.1%$; respectively) [77, 79].

Strength capacity

Like the findings for functional and cardiorespiratory capacity, combined exercise seems to improve strength capacity in individuals with IDD, with a medium effect size.

For the population in focus, the strength training show a statistically significant effect on muscular strength of adults with IDD (SMD = 0.92; 95% CI = 0.40 to 1.45; $z=3.43$; $p=0.000$). The results revealed that both sets of studies produced statistically significant gains in muscular strength, with the non-combined strength training interventions being more effective (SMD = 0.82; 95% CI = 0.32 to 1.31; $z=3.25$; $p=0.001$) compared with the combined interventions (SMD = 1.16; 95% CI = 0.23 to 2.09; $z=2.45$; $p=0.01$) [32a]. Although the effect size is higher than that found in our study, the authors only assessed strength, and for the promotion of other variables, combined training may be more effective. Assessing variables of strength, after participants were part of a training program of this physical capacity, Sugimoto et al. [75] found significant differences and a large effect of the intervention on knee extension strength (SE: 0.52, 95% CIs: 0.31, 0.72, $p=0.01$), a moderate effect (SE: 0.45, 95% CIs:

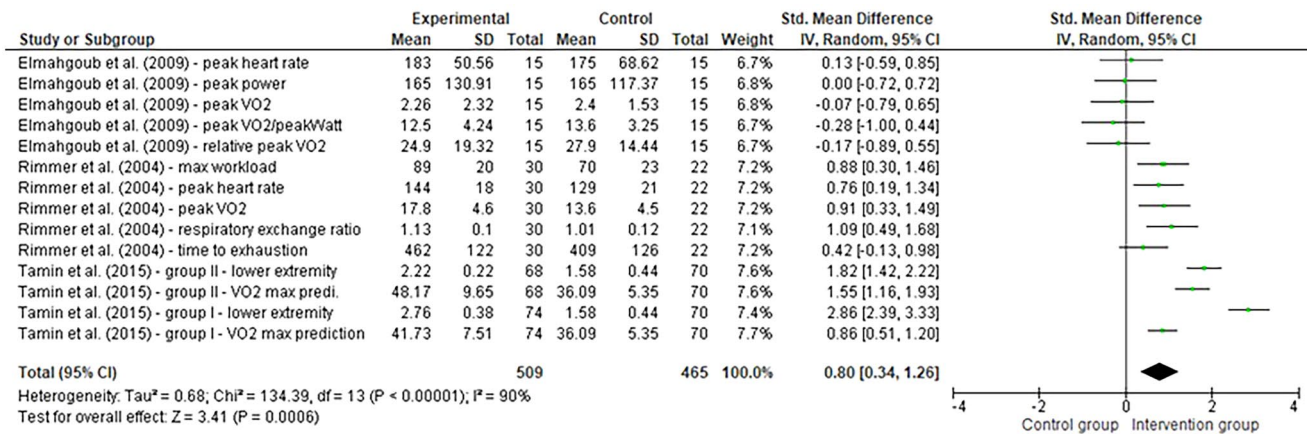


Figure 10. Forest plots showing the effects of combined exercise on cardiorespiratory capacity.
Note: SD, Standard Deviation; CI: Confidence Interval; IV, Inverse Variance.

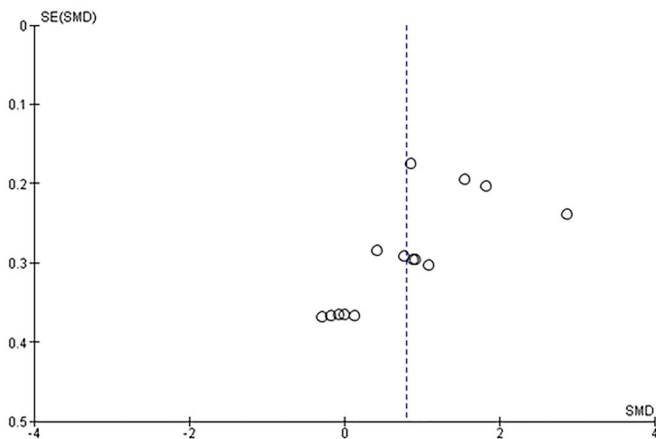


Figure 11. Funnel plot of publication bias of cardiorespiratory capacity.

0.21, 0.68, $p=0.01$) of the intervention on knee flexion strength, a moderate effect of the intervention on 1 RM leg press with statistical significance (SE: 0.40, 95%CI: 0.03, 0.78, $p=0.04$). On the other hand, a small, statistically non-significant effect (SE: 0.21, 95%CI: -0.16, 0.57, $p=0.27$) of the intervention on 1 RM chest press was found [75], similar to what we observed in other studies, where the authors only assess physical capacities related to the type of training.

Various types of exercise in the same analysis [61], showed an effect estimate indicating strong, positive increase when comparing the intervention group to the control group, SMD = 0.70, 95% CI [0.24, 1.16], indicating benefit, although this is a smaller effect size compared to that found in our study.

Shin and Park [30] evidenced a medium effect size (i.e., effect sizes .3–.8) to large effect (i.e., effect sizes larger than 0.8), in physiological measures variable (which included variables such as strength or cardiorespiratory capacity), when performing a meta-analysis with all types of training together. In Wang et al. study [76], the authors did not proceed to a meta-analysis because the existence of few studies did not allow it, a fact not taken into account in some studies.

For populations with other comorbidities, namely after stroke disease and heart failure, combined exercise significantly increased muscle strength (mean ES = .59, 95% CI = .32 to .86, $p<.0001$; SMD = 0.67, 95%CI 0.18–1.16, $I^2=0\%$; respectively) [77, 79], effect sizes smaller than those found in our study.

The first study that analysed the impact of combined exercise showed that it increased cardiorespiratory capacity and decreased the capacity to increase strength [80]. Several factors may explain this lack of significant results (as well as in the variables previously presented), namely the volume, intensity, frequency of sessions or duration of sessions. From the evidence available nowadays, including from the results of the present study, combined exercise seems to increase strength capacity.

Limitation and future research

Although our systematic review with meta-analysis focused only on randomized controlled trials, which is a strength of this work, it is not without limitations. Some articles reviewed did not report the etiology and severity of IDD, and the heterogeneity and lack of information prevented subgroup analysis by age group, gender, or level of IDD. The small sample size of the primary studies may have contributed to large confidence intervals and limited the robustness of the analysis. Additionally, the lack of clarity in intervention protocols, including intensity and monitoring of physical activity, poses further limitations. As a result, caution should be exercised when interpreting the results, and the potential for bias or overestimation of the intervention effect should be considered due to limitations in study designs and methodological quality. The heterogeneity in meta-analyses with significant results and the crossing of the null line in some analyses also warrant careful interpretation of the findings.

Only two studies in our analysis calculated the sample size [54, 57], which is crucial to detect the desired difference and avoid type II errors with small samples or ethical concerns with larger samples [81]. Additionally, some studies lack essential information about the intervention protocol, equipment familiarization, verbal instructions, or other strategies such as demonstration or reinforcement [82]. Furthermore, only one study mentioned the minimum percentage of adherence required for inclusion, which could have influenced our results, as high adherence rates have been shown to be more effective [83]. Lastly, language restrictions may have limited the scope of our results. As well as addressing the limitations mentioned above, future studies should investigate ways of promoting the feasibility of people with intellectual disabilities participating in healthy combination exercise programmes.

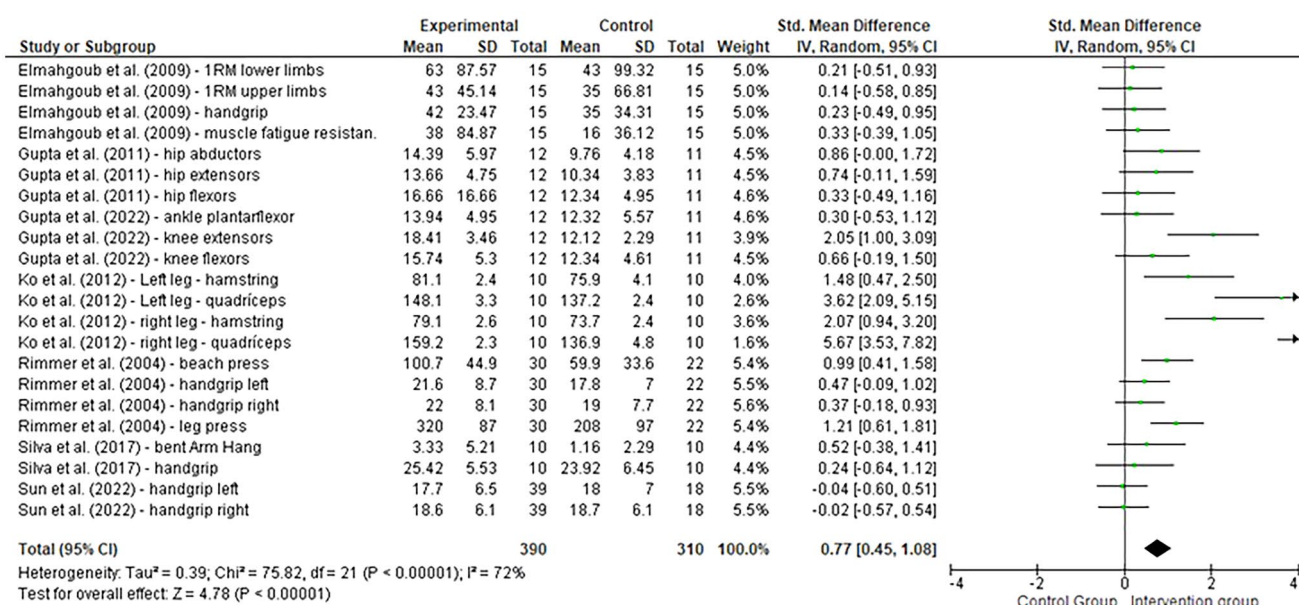


Figure 12. Forest plots showing the effects of combined exercise on strength capacity.
Note: SD, Standard Deviation; CI: Confidence Interval; IV, Inverse Variance.

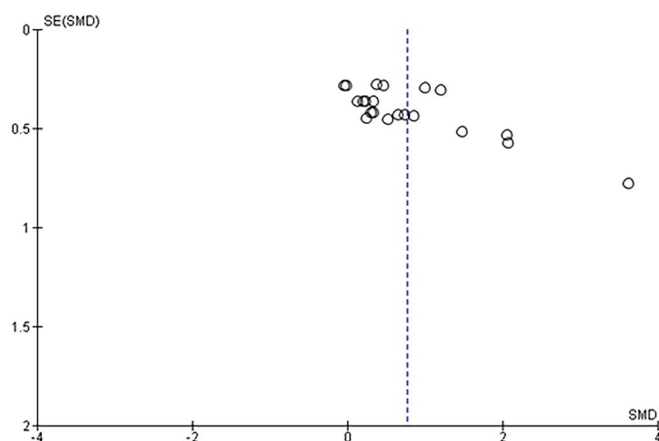


Figure 13. Funnel plot of publication bias of strength capacity.

Conclusion

The findings of this systematic review with meta-analysis suggest that participants engaged in combined training programs show improvements in various variables. However, statistically significant results were observed only for functional capacity, cardiorespiratory capacity, and strength variables. Given the diverse methodologies used in the studies reviewed, it is challenging to establish definitive guidelines for the ideal prescription of combined training to promote all variables in individuals with IDD. Engaging in combined exercise not only enhances physical capacities but also reduces the risk of various diseases, contributing to an improved quality of life for individuals with IDD.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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